Hawaii Agricultural Experiment Station
College of Tropical Agriculture and Human Resources • University of Hawaii
January 1979 • Departmental Paper 42

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ACKNOWLEDGMENTS

The author wishes to thank Yeuh-heng Yang, Research Associate, The Resource Institute, East-West Center; Professor Ira J. Lichton, Department of Food and Nutritional Sciences, College of Tropical Agriculture and Human Resources, University of Hawaii; and Professor, Emeritus, Perry F. Philipp, Department of Agricultural and Resource Economics, College of Tropical Agriculture and Human Resources, University of Hawaii, for their various comments and suggestions, and Stuart Nakamoto, graduate student, for his assistance in collection of data and computation.

This research was supported by United States Department of Agriculture Grant No. 12-14-5001-121.

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Wen-yuan Huang was Assistant Agricultural Economist, Deparment of Agricultural and Resource Economics, College of Tropical Agriculture and Human Resources, University of Hawaii, 1975–78.

COMPARATIVE FOOD VALUES OF SWEET POTATOES IN HAWAII

Wen-yuan Huang

ABSTRACT

Roots and tops of sweet potatoes were evaluated for food energy value and nutrient contents. In 1976, consumers received 1132 calories of food energy per dollar spent on sweet potato roots compared with 4828 and 6712 calories per dollar spent on rice and wheat flour, respectively. Although young shoots are relatively high in nutrient content, this superiority becomes insufficient because of relatively low yields and inefficient cultural methods.

INTRODUCTION

Most of the energy food consumed in Hawaii is imported. In light of the increasing cost of importing food, it is of utmost importance to Hawaii's economy to find crops that can be grown locally and that will provide low-cost energy food. The sweet potato (*Ipomoea batatas*) is a crop that may have this potential.

In tropical areas, the sweet potato outperforms other staple crops in producing calories per acre per day, and it is rated as the crop that has the greatest potential as an energy food in the tropical areas of the world (Krauss, 1974). It has considerable untapped genetic potential (DeVries et al., 1967) and has been recognized as one of the 12 most important crops for feeding the world's current and future populations (Anonymous, 1966).

Historically, the sweet potato has been important as an emergency food. For example, in the United States the root of the sweet potato played an important role in feeding the population during the Civil War (Miller and Hernandez, 1970) and during the economic depression of 1931–37 (Edmond, 1971). Sweet potatoes were frequently used in different parts of the world as a means of preventing famine (Cooley, 1961). In Japan, sweet potatoes repeatedly prevented widespread starvation during years of rice crop failures and also during World War II (Gadiz and Bautista, 1967).

Dr. R. L. Villareal (1975), plant breeder and head of the Department of Plant Breeding at the Asian Vegetable Research and Development Center in Taiwan, concluded that the sweet potato deserves attention as a food crop because of its high-yield potential, high nutrient yield, dependability, acceptability to Asians, inexpensiveness, and versatility in use.

The objective of this report is to analyze the economic potential in Hawaii of using the sweet potato root as an energy food and the sweet potato top as a vegetable. To accomplish this objective, this report has been divided into three parts: the first part reviews the utilization of sweet potatoes as food; the second and third parts, respectively, consider the economic potential of using the root as energy food and the young shoot as a vegetable in Hawaii. Comparative food values based on energy values are used to appraise the food potential of the root. Calories per acre per day and calories per dollar spent by consumers are used to evaluate the food value of the sweet potato root, while comparative overall nutrient content per acre per crop is used to appraise the food value of the top.

UTILIZATION OF SWEET POTATOES AS FOOD

Nutritional Value of Sweet Potato Shoots and Roots

Both the young vines and the roots of the sweet potato can be used for human consumption. Table 1 shows the nutritional values of the young shoots and roots. The young shoots are noted for being relatively high in protein,[1] vitamins, and minerals (as compared with other leafy field vegetables) while the roots are better known for their high caloric values, vitamins, and minerals as compared with rice and corn. A detailed comparison is given later in this report.

[1] It should be noted that, despite the relatively high protein content of sweet potato young shoots, one would have to eat about 2 kilograms of the shoots per day in order to meet the minimum daily requirement of 60 grams of protein. They are obviously not a good major source of protein but rather a supplementary one.

Table 1. Composition of young sweet potato shoots (leaf and tender tips) and roots, per 100 g of edible portion

	Young shoots[1]		Roots[2]		
Composition	Raw	Cooked	Raw	Baked in skin	Boiled in skin
Water	87	87	70.6	63.7	70.6
Food energy (calories)	42	41	114	141	114
Carbohydrate (g)	8	9.2	26.3	32.5	26.3
Fiber (g)	1.3	1.2	0.7	0.9	1.0
Protein (g)	3.2	2.6	1.7	2.1	1.7
Fat (g)	0.7	0.2	0.4	0.5	0.4
Ash (g)	1.4	1.4	1.0	1.2	1.0
Calcium (mg)	86	24	32	40	32
Phosphorus (mg)	81	60	47	58	47
Sodium (mg)	5	–	10	12	10
Potassium (mg)	562	–	243	300	243
Iron (mg)	4.5	0.6	0.7	0.7	0.7
Vitamin A (IU)	4500	2908	8800	8100	7900
Thiamine (mg)	0.13	0.07	0.1	0.09	0.09
Riboflavin (mg)	0.26	0.18	0.06	0.07	0.06
Niacin (mg)	0.90	0.07	0.6	0.7	0.6
Ascorbic acid (mg)	21	1	21	22	10

[1]Source: U.S. Department of Health, Education and Welfare, 1973.
[2]Source: U.S. Department of Agriculture, 1963.

Sweet Potato Production and Utilization in Hawaii

Although the sweet potato is usually assumed to be of American origin (Dixon, 1932), it has been speculated that the crop was developed in Polynesia and carried by the Polynesians to America (Cooley, 1961). Next to poi,[2] the sweet potato was probably the main diet of ancient Hawaiians. In 1778, Captain James Cook recorded finding the sweet potato as a crop in Hawaii. Chung (1923) indicated that the ancient Hawaiians had considerable skill in the cultivation of the crop and had probably grown the sweet potato in Hawaii since about 500 A.D.

After the discovery of the Hawaiian Islands, by Captain Cook, sweet potato production gradually diminished as the native Hawaiian population decreased. Temporary upturns occurred during the whaling years and when the Hawaiian sweet potato was exported to California in the Gold Rush days. In 1910, some trial shipments were conducted to California to test the possibility of developing winter and spring trade. However, exportation was not commercialized and, later, rigorous quarantine regulations made exportation more difficult (Crawford, 1937).

During World War I, there was renewed interest in growing the crop to make Hawaii independent of imported food. Sweet potatoes were used in place of imported Irish potatoes for food, and as a substitute for barley and oats as food for farm animals, and instead of wheat and corn for poultry. At one time, about 350 acres of agricultural land were devoted to sweet potato cultivation in Hawaii. After the war, imported food became available and California began to export considerable amounts of sweet potatoes to Hawaii in spite of trans-Pacific shipment costs, the reason being that, in addition to the slightly different flavor, the Mainland product had a better quality and appearance than the local product (Poole, 1955). Sweet potato acreage in Hawaii declined and, just prior to World War II, only about 150 acres were harvested annually.

At the beginning of World War II, annual acreage again increased, reaching about 320 acres by 1946 (Figure 1). Shortly after the end of the war, total acreage declined to the current 90 acres. Productivity per acre, however, increased from 5600 pounds per acre in 1947 to the current 15,200 pounds per acre (Figure 1). Total production declined from 2,470,000 pounds (1946) to 550,000 pounds (1968), then increased again to 1,365,000 pounds (1976). During this postwar period, sweet potatoes were used mainly as food, with very little being used for animal feed.

The history of sweet potato production in Hawaii strongly indicates that production declined when other imported food became available, although no in-depth studies have been made because of a lack of accurate production data. Efforts to promote sweet potato production in Hawaii have had little success in the past.

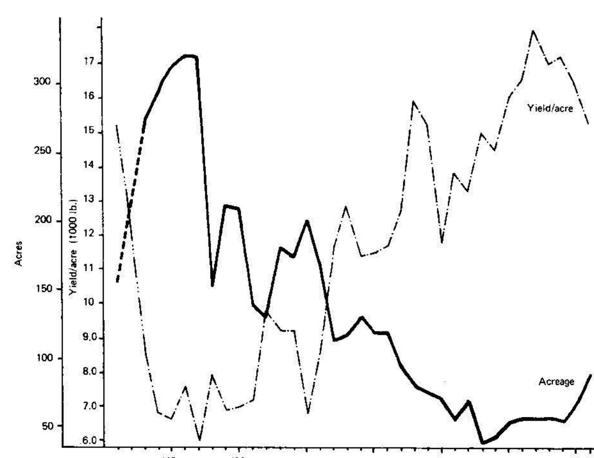
ENERGY VALUE OF SWEET POTATO ROOTS[3]

Selection of Measurement

Consumers generally buy food, not nutrients. However, recent trends indicate that consumers are becoming more

[2]Poi is a pasty, Hawaiian food made from taro roots.

[3]The term "sweet potatoes" used in this section refers to the roots of the sweet potatoes.



Source: *Statistics of Hawaiian Agriculture,* 1941-76.

Figure 1. Sweet potato production in Hawaii 1941-76.

Table 2. Efficiency in producing food energy of some energy crops in Hawaii

Crop	Yield (M.T./ha)[1]	Energy (cal/kg)[2]	Edible portion[2] (%)	Energy[3] (cal/ha)	Period of production cycle (days)	Efficiency (cal/ha/day)
Potatoes	18.42	760	80	11.20×10^6	120	93,328
Taro	20.22	980	84	16.65×10^6	365	45,603
Bananas	11.84	850	68	6.84×10^6	365	18,749
Avocados	11.32	1670	75	14.18×10^6	365	38,845
Sugarcane				107.45×10^6	699	153,720
Granulated sugar	25.76	3510	100	90.43×10^6		
Molasses	7.34	2320	100	17.02×10^6		
Sweet corn	3.25	960	36	1.12×10^6	120	9,360
Sweet potato roots	18.83	1140	81	17.39×10^6	120	144,897

[1]*Statistics of Hawaiian Agriculture* 1975, Hawaii State Department of Agriculture, 3-year average (1973, 1974, and 1975).
[2]*Composition of Foods,* USDA, 1963.
[3]Yield X Energy X Edible Portion.

Table 3. Value of food energy received from sweet potatoes and some imported energy foods in Hawaii, 1976

Crop	Price ($/kg)	Water (%)	Food energy (cal/kg)	Edible portion (%)	Energy cost[1] ($/cal)	Energy worth (cal/$)	Energy value[2] index
Rice (short grain)	0.7518[3]	12	3630	100	2.071×10^{-4}	4828	3.93
Wheat flour	0.5423[3]	12	3640	100	1.490×10^{-4}	6712	3.94
Potatoes	0.6623[3]	80	760	80	10.893×10^{-4}	918	0.66
Sweet potatoes	0.8157[4]	70	1140	81	8.833×10^{-4}	1132	1.00
	0.5952[5]	70	1140	81	6.446×10^{-4}	1551	

[1]Energy estimate = Price/food energy.
[2]Formula for computing index: $I_i = (f_i \times e_c) / (f_s \times e_s)$
where f_i is the food energy per kg of food i
f_s is the food energy per kg of sweet potato
e_i is the edible portion of food i
e_s is the edible portion of sweet potato.

[3]*Estimated Retail Food Prices by City,* 1968–1977, Bureau of Labor Statistics, U.S. Department of Labor.
[4]Estimated 1976 average retail price is $0.37/lb.
[5]1976 average wholesale price.

Table 4. Comparison of nutritional values of young sweet

Vegetable	Yield[2] (kg/ha)	Period of growth (days)	Efficiency (kg/ha/day)	Composition of food per 100 g of edible portion: Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (I.U.)	Thiami (mg)
Head lettuce	16,740	70	239	1.0	18	0.4	2950	0.04
Watercress	57,835	365	158	1.7	114	1.9	1708	0.07
Celery	47,636	90	529	1.4	62	2.5	1040	0.06
Chinese cabbage	26,676	60	445	1.7	102	2.6	3841	0.07
Head cabbage	31,789	80	397	1.6	55	0.8	467	0.06
Sweet potato	13,000[3]	120	108	3.2	86	4.5	4500	0.13
Young shoot	(6,000)	(100)	(60)					

[1]U.S. Department of Health, Education, and Welfare, 1973.
[2]Yields are 3-year averages (1973–75) except for the young shoots of sweet potatoes.

aware of the nutritional value of the food they eat and are more interested in buying food for its nutritional content. Evaluating food values based on nutrient content is a generally accepted procedure.

There are many ways of evaluating the food value of an agricultural product, based in nutritional content, although none of them is perfect. The food-energy approach is considered to be adequate if the main function of the crop is to provide carbohydrates. This is the case with the sweet potato. Basically, the energy value of the root is computed from the amount of carbohydrate, protein, and fat in a given amount of root. Data on the energy values of most agricultural products are available and provide basic information for the comparison of food values. Thus, food energy is used as the basic measurement for evaluating the food potential of sweet potatoes.

It should be noted that in this report the conclusions regarding the food potential of sweet potato roots were made primarily on the basis of food-energy values. There might be a situation in which a comparison of efficiencies in producing protein, vitamins, and ascorbic acid as well as fiber content should be included in an analysis of food values.

Efficiency in Producing Food Energy

Two types of comparisons were made to determine the food value of sweet potatoes in Hawaii. First, the food-energy production efficiency of the sweet potato is compared with the food-energy production efficiency of other energy crops currently growing in Hawaii. Second, the food energy (calories) received by a consumer spending one dollar on sweet potatoes is compared with the energy received from spending one dollar on alternative energy foods.

Taro, bananas, avocados, sweet corn, and sugarcane have been selected for the first comparison, and imported rice, wheat flour, and Irish potatoes are used in the second comparison. The results of these two comparisons are then used to evaluate the food potential of the sweet potato in Hawaii.

Table 2 shows the efficiency of providing food energy from sweet potatoes as compared with selected energy crops in Hawaii. The results, in the last column of the table, indicate that sugarcane has the highest efficiency (defined in terms of calories per hectare per day) in producing food energy. Among the starch foods, however, sweet potatoes outperform other crops. Per hectare of land, sweet potatoes were estimated to produce 144,897 calories per day, with Irish potatoes next at 93,328 calories per day. Taro, avocados, bananas, and sweet corn are less efficient in producing food energy. The results imply that sweet potatoes are the highest yielding emergency crop to be grown for food in Hawaii if imported energy food is cut off. The results also substantiate the fact that historically sweet potatoes have repeatedly served as an emergency food for human beings. In addition, sweet potatoes in tropical areas such as Hawaii are considered to have a higher efficiency in producing food energy than other staple foods, such as rice, wheat, and cassava (Krauss, 1974).

Since Hawaii imports considerable amounts of wheat flour and rice, the next logical question is: Is it cheaper, in terms of food energy received per consumer dollar spent, to use wheat flour or rice instead of sweet potatoes as an energy food?

The food-value index in Table 3 indicates that each pound of rice and wheat flour will generate, respectively, 3.93 and 3.94 times the food energy of 1 pound of sweet potatoes. Table 3 also indicates that it was cheaper at 1976 prices to obtain energy from imported wheat flour or rice

otato shoots with selected leafy vegetables in Hawaii

purchased[1]		Nutrient yields per hectare per day					
Vitamin C (mg)	Water (%)	Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (I.U.)	Thiamine (mg)	Vitamin C (mg)
12	95.8	2390	43,020	957	7,050,500	95.5	28,680
46	93.8	2690	180,120	3,002	2,698,640	110.6	72,680
20	92.8	7410	327,980	13,230	5,501,600	317.4	105,800
53	94.2	7570	453,900	11,570	17,092,450	311.5	235,850
46	93.0	6356	218,350	3,180	1,853,990	238.2	192,620
21	86.7	3460	92,890	4,960	4,860,000	140.4	22,680
		(1920)	(51,600)	(2,700)	(2,700,000)	(78)	(12,600)

Average of 13,000 kg per hectare was obtained from 1½-month-old sweet potato plants by Dr. R. L. Villareal at AVRDC in an experiment in which only 15-cm tips are harvested on 10-day intervals. (Personal communication with author, July 20, 1977.) Average of 6000 kg per hectare could be obtained without affecting the yield of the root (Villareal, 1975).

Table 4. Comparison of nutritional values of young sweet potato shoots with selected leafy vegetables in Hawaii

Vegetable	Yield[2] (kg/ha)	Period of growth (days)	Efficiency (kg/ha/day)	Composition of food per 100 g of edible portion as purchased[1]: Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (I.U.)	Thiamine (mg)	Vitamin C (mg)	Water (%)	Nutrient yields per hectare per day: Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (I.U.)	Thiamine (mg)	Vitamin C (mg)
Head lettuce	16,740	70	239	1.0	18	0.4	2950	0.04	12	95.8	2390	43,020	957	7,050,500	95.5	28,680
Watercress	57,835	365	158	1.7	114	1.9	1708	0.07	46	93.8	2690	180,120	3,002	2,698,640	110.6	72,680
Celery	47,636	90	529	1.4	62	2.5	1040	0.06	20	92.8	7410	327,980	13,230	5,501,600	317.4	105,800
Chinese cabbage	26,676	60	445	1.7	102	2.6	3841	0.07	53	94.2	7570	453,900	11,570	17,092,450	311.5	235,850
Head cabbage	31,789	80	397	1.6	55	0.8	467	0.06	46	93.0	6356	218,350	3,180	1,853,990	238.2	192,620
Sweet potato	13,000[3]	120	108	3.2	86	4.5	4500	0.13	21	86.7	3460	92,890	4,960	4,860,000	140.4	22,680
Young shoot	(6,000)	(100)	(60)								(1920)	(51,600)	(2,700)	(2,700,000)	(78)	(12,600)

[1]U.S. Department of Health, Education, and Welfare, 1973.

[2]Yields are 3-year averages (1973–75) except for the young shoots of sweet potatoes.

[3]Average of 13,000 kg per hectare was obtained from 1½-month-old sweet potato plants by Dr. R. L. Villareal at AVRDC in an experiment in which only 15-cm tips are harvested on 10-day intervals. (Personal communication with author, July 20, 1977.) Average of 6000 kg per hectare could be obtained without affecting the yield of the root (Villareal, 1975).

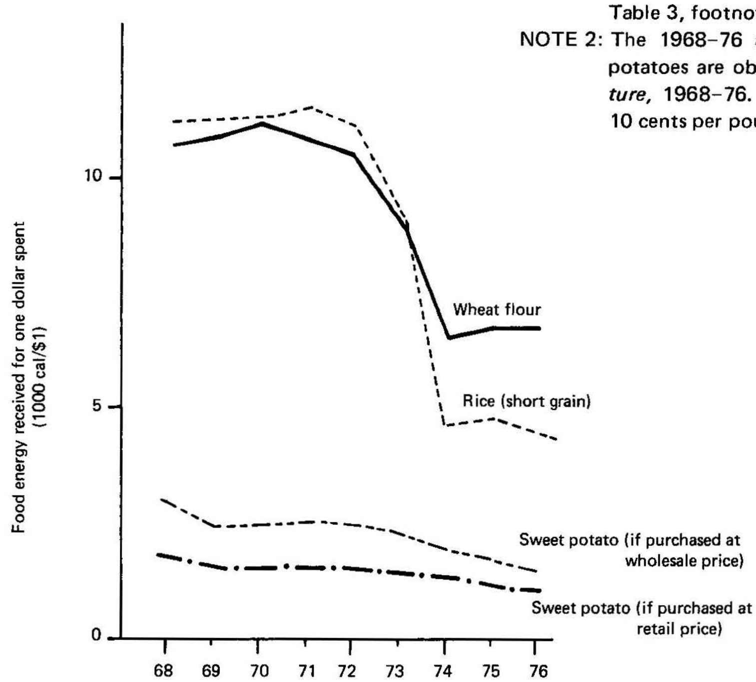


Figure 2. Value of food energy received from sweet potatoes and some imported food in Hawaii 1968–76.

than from sweet potatoes. Figure 2 shows the energy obtained per dollar's worth of sweet potatoes, rice, and flour from 1968 to 1976; the graph indicates that consumers received the least amount of food energy per dollar spent on sweet potatoes. Rice was the cheapest buy for food energy before 1973, after which wheat flour became the least expensive energy source. An interesting observation is that the gap between sweet potatoes and the two imported foods for a dollar's worth of energy has decreased since 1972. At the same time, energy from rice and from flour has become more expensive. The figures indicate that sweet potatoes could become an economical substitute for rice or flour for energy, only if the price per pound of sweet potatoes were less than one-fourth the price of rice or flour.

POTENTIAL OF USING YOUNG SHOOTS AS A VEGETABLE FOOD

Young sweet potato shoots usually are consumed as a vegetable. The food value fo the young shoots was therefore evaluated by comparing nutritional content and yield per hectare per day with other leafy vegetables grown in Hawaii.

Two methods of sweet potato cultivation for producing the young shoots were examined to evaluate their potential as a leafy vegetable in Hawaii. In the first method, it is assumed that sweet potatoes are grown mainly for producing the young shoots. In this method, ratoon cultivation is assumed, with the young shoots harvested at a fixed time interval. In the second method, the sweet potato shoots are grown as a byproduct of root production.

In general, there are insufficient data regarding the yields of young shoots under these two cultivation methods to make any conclusive inferences. However, a preliminary inference was made using yield data obtained mainly from Villareal's experiments in Taiwan and experimental results in the Philippines (Villareal, 1975).

Growing Sweet Potatoes for Young Shoots

The nutritional values of the young shoots and other common leafy vegetables in Hawaii are shown in Table 4. The annual yield of young shoots per hectare was estimated at 13,000 kilograms, from an experiment conducted in Taiwan during 1976 by Villareal.[4] In that experiment, approximately 15-centimeter tips were harvested in a 10-day interval. The nutritional values of the young shoots as well as other leafy vegetables in terms of yield per hectare per day was computed, as shown in Table 4. Among the vegetables listed, the young shoots can be rated as relatively high in nutrient content, in terms of protein, minerals, and vitamins per 100 grams of edible portion as purchased.

[4]Personal communication with author, July 20, 1977.

However, due to the relatively low yields of present varieties and to the poor cultural methods, the superiority of young shoots in nutritional value becomes insignificant when compared with other vegetables. For instance, Chinese cabbage has an overall nutritional yield per hectare per day that is about three times greater than that of the young sweet potato shoots.

Furthermore, it can be expected that the cost of producing young shoots will be higher than that of most other vegetables because frequent selections and harvests are needed. Therefore it can be inferred that it will cost more to obtain nutrients from the young shoots than from most other vegetables growing in Hawaii. If the young shoots are to be an economical vegetable, improvement in yield through use of better varieties or through innovations in cultivation methods to reduce costs is essential.

Young Shoots as a Byproduct of Root Production

Villareal (1975) indicated that sweet potato production that produced 20 tons of roots could also produce 6000 kilograms of young shoots. The figures in parentheses in Table 4 give these nutritional values. These values are less than those of most of the vegetables in the table.

The only expense for young shoots with this production method is the harvesting cost. This cost has to be far less than the cultivation and harvesting costs of other types of vegetables if production of young shoots is to be economical. Although the weight of the young sweet potato shoots is much less than the weight of any one of the other types of vegetables considered, the labor for harvesting the sweet potato, given present cultural methods, is not significantly less than the labor required to harvest another vegetable. Since labor is the main expense in harvesting, it is doubtful that harvesting costs for the young shoots would be significantly less than the harvesting costs for other vegetables. Cost savings from handling less weight would not offset the lower nutritional value per acre of the young shoots. Thus, it is highly unlikely that young sweet potato shoots will prove economical as a leafy vegetable, with present varieties and cultivation methods.

CONCLUSIONS

The root of the sweet potato outperforms other starch crops in Hawaii in producing calories per hectare per day. Among the starch-producing crops, per hectare of land, sweet potatoes were estimated to produce 144,897 calories per day, with Irish potatoes next at 93,328 calories per day. The sweet potato could be considered the best emergency energy food in the event that Hawaii becomes isolated from the Mainland.

Sweet potato roots could become an important food-energy source for Hawaii if import prices for rice and flour become four times greater than the price of sweet potatoes.

Currently (1976), sweet potato roots are a luxury food for obtaining food energy. Imported rice and wheat flour are less expensive food-energy sources. Consumers receive 1132 calories of food energy per dollar spent on sweet potatoes, compared with 4828 and 6712 calories per dollar spent on rice and wheat flour, respectively.

Currently, use of the young shoots as a vegetable is not economically feasible in either of two production situations: growing the sweet potatoes mainly for their young shoots, or producing the young shoots as a byproduct of root production. In terms of protein, minerals, and vitamins per gram of edible portion as purchased, among the vegetables grown in Hawaii, although young shoots are relatively high in nutrient content, their superiority in nutritional value becomes insignificant due to the relatively low yield of the present varieties and to inefficient cultural methods. Use of the young shoots as a vegetable in Hawaii in the near future is feasible only if there is a significant increase in yield and/or a decrease in production costs.

The evaluation methods used and the findings in this report have an immediate application to the developing tropical countries. As the price of imported wheat flour in these countries is found to be four times higher than the price of locally grown sweet potatoes, considerable foreign exchange can be saved by increasing sweet potato production to replace the imported wheat flour in providing food energy. The method used in this study can be applied equally well to evaluate the food value of sweet potatoes in a developing country where the production environment is different.

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